Physical Modeling of CO_2 Sequestration

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Contractor: Stanford University
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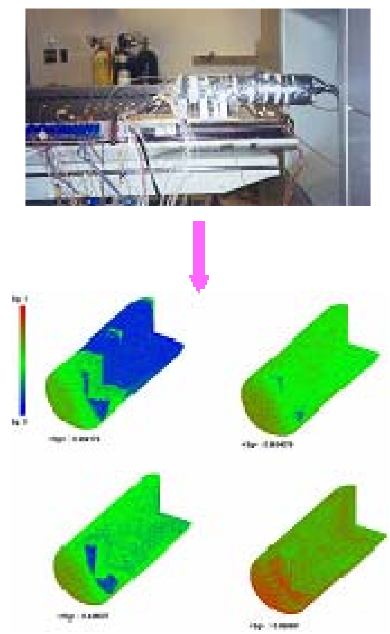
The Issue

Disposal of carbon dioxide (CO_2) from power plants burning natural gas, crude oil, and coal is a key strategy for reducing the atmospheric carbon levels responsible for global warming. One possible disposal method is to sequester CO_2 into deep reservoirs and aquifers.



Using an X-ray scanner, the displacement of gas (red) into water (blue) can be visualized and measured. This will allow the measurement of CO_2/water relative permeability.

The relative permeability of water/CO_2 flow in such reservoirs would play an important role in CO_2 injection and sequestration, as well as in the evaluation of CO_2 leakage from geologic disposal reservoirs. Engineering risks would be reduced if reliable relative permeability estimates could be obtained.

Another important factor influencing the performance of CO_2 injection and sequestration is CO_2 interaction with the water that exists in reservoirs. The solubility of CO_2 in water influences the effectiveness of CO_2 storage in reservoirs. However, fundamental understanding of the interaction between two-phase flow mechanisms and solubility mechanisms is still poor.

This project provides a clearer understanding of the chemistry involved in CO_2 sequestration and thus enables a more certain estimate of its feasibility.

Project Description

This project—funded by PIER's Environmental Exploratory Grants Program—physically modeled the fluid flow of water/CO_2 systems, using a modification of a device developed earlier by Stanford's geothermal research group to study steam-water flow. Pressure, temperature, and flow rates during water/CO_2 two-phase flow were recorded by a data acquisition system. Once these data were available, relative permeability and other fluid flow properties could be calculated. Liquid saturation and its distribution were monitored using an X-ray CT scanner. Finally, the water/CO_2 two-phase relative permeability curves as well as the features of the distribution of fluid saturation were obtained.

The main tasks were as follows:

- Modify and construct the experimental apparatus to model fluid flow and to measure relative permeability in water/CO_2 systems
- Conduct the physical simulation of two-phase water/CO_2 flow in a porous medium
- Measure relative permeability in water/CO_2 systems using an X-ray CT scanner
- Conduct theoretical studies and understand the mechanisms of water/CO_2 two-phase flow
- Develop mathematical models of water/CO_2 two-phase relative permeability for application to reservoir engineering

The principal technical contribution of this project is the measurement of fluid flow in water/CO_2 two-phase systems. This information will be useful to engineers, scientists, and state agencies in planning future strategies for CO_2 injection and sequestration.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objective:

- **Resolving the environmental effects of energy production and use.** CO_2 sequestration into deep reservoirs and aquifers is a promising approach to reducing greenhouse gases in the atmosphere. Sequestration technology would enable the continued use of fossil energy with less impact on environment. This research will reduce the uncertainty in engineering evaluations, thereby lowering the risks and associated costs of CO_2 sequestration.

Project Results

By measuring the relative permeability of carbon dioxide gas and water in an experimental apparatus, this project determined that CO_2 solution and dissolution phenomena have a large effect on the displacement of CO_2 gas into water. This result has significant implications for CO_2 sequestration into aquifers. The observed reduction in the residual liquid saturation implies that a much greater quantity of CO_2 could be sequestered than would be suggested based on simple relative permeability concepts alone. Simulations of CO_2 sequestration using numerical models based on simple relative permeability functions are likely to misrepresent the physical outcome of CO_2 injection into aquifers. Current numerical simulation programs will need to be modified to incorporate the combined influences of solution/dissolution and relative permeability.

Final Report

The final report for this project can be downloaded from www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2007-113.

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